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A multidimensional outlook to energy investments for the countries with continental shelf in East Mediterranean Region with Hybrid Decision Making Model based on IVIF logic

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ABSTRACT

This study aims to identify the influencing factors of the effectiveness in energy investment. For this purpose, 8 different countries with continental shelf in the Eastern Mediterranean region (EMR) are considered. Firstly, 9 different criteria are defined based on the literature review. The significance levels of these factors are determined by considering hesitant interval-valued intuitionistic fuzzy (IVIF) DEMATEL based on 2-tuple linguistic values (2TLV). Therefore, the motivation of this study is to figure out the weights of the criteria for the energy investment projects. Also, the main contributions to the literature are to propose a set of criteria for defining the indicators of the efficiency and to construct a novel decision-making model based on IVIF technique in these projects. The main justifications of this hybrid method can be given as the importance of the distribution, political stability, and technological capacity for the effectiveness in energy investment. Furthermore, hesitant TOPSIS method is used to evaluate these 8 countries regarding the effectiveness in energy investments. It is concluded that Israel and Turkey are the most successful countries in this framework. It is recommended that these countries should have an effective pipeline to transfer the reserves to other countries. Also, these countries in this region should pay attention to political stability. Moreover, countries with energy reserves in the EMR should make the necessary investments to improve their technological infrastructure. Hence, seismic exploration and drilling vessels should be obtained by these countries so that the energy reserves can be located and obtained effectively.

1. Introduction

Energy is an important resource for the infrastructure of industrialization and an indispensable element of daily life. Thus, it is possible to say that energy affects a country both socially and economically. Because it is the raw material of the industry, energy has a vital importance in the economic development of the country. Countries must supply this energy they need to develop their industry and achieve economic growth. Otherwise, it will be difficult to achieve sustainability in the country's economic development (Lin and Chen, 2020). On the other hand, with the help of the energy, people can satisfy their daily needs, such as energy, warming and enlightenment. Since they are the basic needs of people, it is essential to supply energy in this sense. In the contrary, when the basic needs of citizens are not met, it will cause social problems to arise (Palm and Thollander, 2020). Due to these issues, energy policies have an important role in the future strategies of the countries.

It is obvious that countries must supply this energy they need. The important point here is whether countries have sufficient energy resources. Countries with their own energy resources can supply this energy they need at a very low cost. However, a country must supply the energy it needs from outside when there is not enough domestic source. In other words, this country is becoming foreign dependent on energy. This situation increases the vulnerability of the country in macroeconomic terms. For example, the current account balance of a country will be negatively affected by this situation. In addition to this problem, a country that must buy energy from foreign countries also faces foreign currency risk. Since these countries purchase energy in currencies such as American dollar (USD) and Euro, the purchased energy will also become more expensive if these currencies gain value. This will negatively affect the performance of the country's economy (Przychodzen and Przychodzen, 2020). Due to these problems, countries desire to have their own energy resources.

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Within this context, they aim to reduce their external dependence on energy by giving importance to strategies such as the searching for energy reserves and the usage of renewable energy.

Energy reserves in the Eastern Mediterranean region (EMR) attract the attention of countries in this regard. According to the research of the American Geological Association (USGS), it is estimated that there are 223 trillion cubic feet of recoverable gas for Nile Delta Basin Province[1] and 122 trillion cubic feet of recoverable gas for Levant Basin Province.[2] On the other hand, according to the same research reports, it is also thought that there is a significant amount of oil in the region. Also, the researches continue and perhaps the size of the energy reserves detected in the region may be more. The size of these energy reserves has attracted the attention of both the countries that have a coast to the region and big energy companies. Because of these issues, the countries and companies have started to search for natural gas in these regions. The countries bordering the region, such as Greece, Turkey and Israel continue their exploration activities in this area. Additionally, France, Italy, the United States and South Korea, which do not have a coast to the region, also play an active role in this process (Demiryol, 2019).

The economic size of these energy sources causes the countries of the region to experience political problems from time to time. One of the biggest problems in this region is located on the island of Cyprus. Since both Turks and Greeks live in this island, these groups have declared their exclusive economic zones. These two declared regions intersect with each other. This situation causes a political tension between these two groups (Heraclides and Çakmak, 2019). In addition, the continental shelf dispute between Turkey and Greece are experiencing. This situation increases the political tension between these two countries. One of the major developments in this area is the continental shelf agreement signed between Turkey and Libya. This agreement increased political problems between Libya and Greece. This situation was also experienced between Israel and Lebanon (Bilgin, 2019). Due to these problems, the navies of the countries also ensure the security of the teams engaged in energy exploration in this region.

It is quite significant that these specified energy sources can be used effectively by countries. First, it is important to resolve political problems between these countries. In addition, there are other factors necessary to use these energy resources effectively (Wu et al., 2020). The gas is located under the sea in the Mediterranean region. Therefore, countries need sufficient technical equipment and staff to provide these reserves (Zhou and Qin, 2020). In this context, seismic exploration vessels that can locate energy sources and drilling vessels are needed to extract the detected gas. Countries with these vessels may gain an important advantage over others. Furthermore, it is very important that the personnel working in this process have necessary technical qualification (Mahama et al., 2020). In this way, it will be possible to solve a possible technical defect in the ships in a short time.

Another important issue in this process is how to transfer the extracted gas. The main reason is that it is very difficult to move the energy reserves in the EMR to Europe and other countries. East-Med is one of the most popular routes in this process. The main purpose here is to transfer the energy reserves of Israel to Europe via Cyprus and Greece (Lerman, 2019). This project is also supported by the European Union. However, there are some problems in this project. First, the cost of the project is estimated to be around $7 billion which causes a financial problem. Additionally, to realize this project, it is necessary to reach a depth of 3.5 kilometers and reach a length of 2100 kilometers. Trans Anatolian Natural Gas Pipeline (TANAP) is another distribution channel that stands out in this process. This line plans to transfer the Azerbaijani gas to Europe via Turkey pipeline (Sopilko and Illeritsky, 2019). Hence, with this project, it can be possible to transfer the gas in EMR to Europe via Cyprus and Turkey. As can be seen from these examples, the efficient distribution of the energy obtained will also contribute to the beneficial use of these energy sources. Moreover, it is very difficult for countries with economic vulnerability to follow an effective policy in this process (Anton and Nucu, 2020). In parallel, internal conflict in a country will also hinder the implementation of an effective energy policy (Boute, 2020). On the other hand, political problems between countries complicate the work of the energy companies (Meyer, 2020). Therefore, navies belonging to those countries generally protect these energy companies in the region. Furthermore, many countries in the EMR prepare themselves for possible tension by performing exercises. Hence, the stronger military provides the countries an important advantage in using the energy resources in this region more effectively.

It is obvious that the studies on the efficient use of energy resources in the EMR should include many different issues such as technological competence, distribution channels, economic and military power. Otherwise, there is a risk that the analysis will produce erroneous results and the wrong strategies can be developed. Another important point in this process is related to the methodology. If the method in this analysis is not suitable for the study, the validity of the results will be questioned. Multi-criteria decision-making methods (MCDM) are used in the studies within this framework (Eghtesadifard et al., 2020). These methods are generally preferred in determining what matters are more important when there are many different factors. They are mainly used in conjunction with fuzzy logic (Ulutaş et al., 2020). In this way, it is aimed to handle the uncertainty in this process (Sałabun and Urbaniak, 2020). Based on this information, it is considered that fuzzy MCDM will yield successful results in studies aiming to use energy resources in the EMR effectively.

It is aimed to determine the factors that affect the effectiveness of countries in energy investments in this study. Within this framework, 8 different countries with continental shelf in the EMR are included in the scope of the study. In the analysis process, firstly, a literature review is carried out and 9 different criteria that may affect the success of countries' energy investments are identified. After that, hesitant interval-valued intuitionistic fuzzy (IVIF) decision making trial and evaluation laboratory (DEMATEL) method based on 2-tuple linguistic values (2TLV) is used to determine which of these criteria is more important. On the other hand, in the last part of the analysis process of the study, 8 EMR countries included in the scope of the study are listed according to their success in energy investments in this region. In this process, the IVIF technique for order preference by similarity to ideal solution (TOPSIS) method based on 2TLV is preferred. Hence, the motivation of this study is to figure out the weights of the criteria for the energy investment projects. Furthermore, the main justifications of this hybrid method can be given as the importance of the distribution, political stability, and technological capacity for the effectiveness in energy investment.

The main reason of selecting DEMATEL in the analysis process is that this method also provides impact-relation map between the factors unlike similar methods in the literature, such as analytic hierarchy process (AHP) and analytic network process (ANP) (Song et al., 2020; Roy et al., 2020a,b). In other words, the direction of causality relationship between variables can be identified by considering DEMATEL. Moreover, the main reason for using TOPSIS to rank the countries is that both the best and worst alternatives are used in the evaluation. With the help of this issue, when there is a same distance to the positive solutions

1 https://pubs.usgs.gov/fs/2010/3027/pdf/FS10-3027.pdf.
2 https://pubs.usgs.gov/fs/2010/3014/pdf/FS10-3014.pdf.

for two different factors, the distance to the negative solution is considered to find the best alternative (Pang et al., 2020; Chen et al., 2020a). However, some other MCDM approaches like vlsekriterijumska optimizacija i kompromisno resenje (VIKOR) only considers the distance to the positive solution. The simplicity and computational efficiency are other important advantages of TOPSIS approach (Gholipour et al., 2020).

On the other side, owing to the IVIF logic, it is possible to determine extreme limits by using optimistic and pessimistic values within a boundary of linguistic evaluations. In this way, it is aimed to analyze the evaluations of decision makers more clearly (Büyüközkan et al., 2020; Wang and Shi, 2020). Furthermore, in the analysis process, an approach is needed where the opinions of experts with similar ideas can be evaluated as a common decision. The main reason is that not all experts will have the same idea. Thus, the main advantage of hesitant fuzzy sets is that hesitant information can be expressed more comprehensively while comparing with other fuzzy sets (Wang et al., 2019; Liu et al., 2020). Moreover, the main reason of considering 2TLV is that it is possible to determine the intermediate evaluations between two linguistic values more accurately. Additionally, the data can be fuzzified more accurately owing to 2TLV. This situation has a positive influence to reduce the loss of the information. Also, by considering 2TLV in the analysis process, the complexity in decision making process can be minimized (Gupta and Muhuri, 2017; Jin and Huang, 2019).

This study is thought to have some contributions compared to other studies. Firstly, it has been determined that there are few studies in the literature on energy reserves in the EMR. It is observed that these studies generally focus on political issues. However, no study on the effectiveness of energy investments in this region has been found. Therefore, it is obvious that this study is original in terms of subject. On the other hand, based on literature examination, factors that may contribute the efficiency of energy investments are identified. These criteria guide both decision-makers and academicians on energy. Another originality of the study is related to the methodology. Hesitant IVIF DEMATEL and hesitant IVIF TOPSIS methods are firstly used in relation to energy investments. Hence, proposing a list of criteria and generating a novel decision-making model based on IVIF technique regarding energy investment projects is accepted an important contribution of this study. The economic size of the energy reserves in the EMR causes the countries of the region to have political problems with each other. This situation reduces the efficiency of energy investments in the region. In this study, suggestions can be presented to make these investments more effective. It is concluded that this situation contributes to reduce the problems in the region.

Five different sections are taken place in this study. Firstly, important concepts about the subject are explained. Then, the literature review related to the subject is given in the next part. In this way, it has been possible to identify the missing topic in the literature. The third part includes the theoretical information of hesitant IVIF DEMATEL and hesitant IVIF TOPSIS methods. The analysis results are shared in the next part. In the last part of the study, strategy suggestions for increasing the performance these investments in the region are included. In addition, studies with similar results in the literature are also shared.

2. Literature review

Under this heading, firstly, a literature review for energy investments has been conducted. After that, a literature review has been made for MCDM methods. Thirdly, decision making literature in energy investment is reviewed. Finally, the findings obtained as a result of the literature analysis are shared.

2.1. Literature review on energy investments

Energy investments have an impact on both the economic and social improvement of countries. Thus, it is crucial to increase the effectiveness of these investments. It is quite difficult to ensure effectiveness, especially in the use of large-scale reserves. Hence, many different factors should be considered at the same time to achieve this goal. For instance, Boute (2020) focused on the relationship between regulatory stability and renewable energy investment in Kazakhstan. It is stated that political stability is an important factor in this process. Energy projects are large-scale and long-term investments. For this reason, it is necessary to maintain the management of the political power in the country in a stable manner. Franza et al. (2020) conducted a research for Southern and East Mediterranean (SEMED) countries and reached the same result. Another issue to be considered to raise the efficiency of energy investments is cost analysis. Majid (2020) made a study regarding the importance of the renewable energies in the sustainable development of India. He defined that It is much more difficult to provide an energy reserve that is kilometers below the ground compared to extracting energy resources closer to the ground. In this difficult situation, a serious mechanism must be created to obtain energy reserves. This will increase the cost of providing energy. Therefore, for energy investments to be effective, it is important to carry out this cost analysis in a very detailed manner. Salehi et al. (2020) also discussed the energy projects in Iran and emphasized the importance of cost analysis. Moreover, distribution of the energy to the countries has an impact on the effectiveness of these investments (Zhang, 2020). For example, in a situation where energy resources are also below the sea such as the EMR, it is an important event how these reserves will be delivered to other countries. Laguna-Martinez et al. (2020) examined the energy investments in Mexico and argued that the cost of distribution of energy should be reduced to improve the efficiency of energy investments.

On the other hand, another important issue in energy investments is technological competence. Energy projects contains extensive technical knowledge and are not easy to realize. Hence, for the success of energy investment company, technological power plays a key role. McCabe (2020) tried to examine the major producers of crude oil and natural gas. It is identified that the company must have technological competence to increase efficiency in energy investments. Hu et al. (2020a,b) also used regression and cointegration methods while analyzing energy projects in the USA. It is argued that energy investments cannot be effective if the company is not technologically sufficient. Furthermore, Zhou and Qin (2020) studied energy projects in China and emphasized the importance of the technological infrastructure for the success of these projects. In addition, the quality of energy reserves also affects the efficiency of investments. The main reason is that if the reserves are of poor quality, the income from these energy investments will decrease. This will reduce the effectiveness of these projects. Qadrdan et al. (2020) focused on the energy investment projects in UK and stated that the reserves should be of high quality. Gorre et al. (2020) and Harrigan et al. (2020) also achieved similar results for different country groups.

Countries should also have military power to make more effective energy investments. Energy is an indispensable need for all countries. However, energy resources may not be available in sufficient amounts in every country. This situation occasionally causes problems between countries (Smith and Gülen, 2020). In this process, countries with military power can gain an important advantage compared to others. Meyer (2020) examined energy investments in 11 different countries. It is determined that the military power of countries is at least as important as technological and economic factors for the effectiveness of these investments. Furthermore, economic power also contributes to the effectiveness of energy investments. Thus, for a country to successfully implement its policies regarding energy investments, it must first be economically strong. Within this context, there should be no vulnerabilities in the economies, such as high inflation, current account deficit and unemployment. Anton and Nucu (2020) and Ahmad et al. (2020) stated that one of the factors affecting the efficiency of energy investments in different country groups is the economic power of the country.

Additionally, it is also necessary to have qualified employees for this purpose. Serious engineering knowledge is required to realize energy projects. Within this framework, energy investment companies are required to employ personnel who have necessary qualifications related to this subject. This issue has been emphasized in many different studies. Mahama et al. (2020) focused on energy projects in Ghana by conducting a survey analysis. In this study, the importance of the technical knowledge of the staff was emphasized. On the other hand, Kealy (2020) and Onyango (2019) have also studied energy projects in Ireland and Qatar. It was stated that the personnel play a key role in increasing the efficiency of energy projects. Also, the amount of energy reserves is crucial in the effectiveness of these projects. Since energy projects contain high costs, the high amount of reserves will have a positive effect on the profitability of these projects (Qiu, 2020). Otherwise, investing in areas with insufficient reserves will also reduce the effectiveness of these projects (Nyambuu and Semmler, 2020).

2.2. Literature review on MCDM methods

One purpose of the use of MCDM methods is to determine more significant criteria that affect a purpose. There are different approaches in the literature in this regard. AHP method has been considered in many studies in this context. As an example, Lyu et al. (2020) aimed to analyze the risks at metro stations in Shenzhen. Within this framework, the more important risks among the different ones have been identified with the help of this technique. Incapability of reflecting uncertain human's thoughts is the main criticism of AHP approach (Connett et al., 2019; Trzaskalik et al., 2019). ANP is another method considered in determining the weights of the factors. It determines the relationships and directions between the criteria. Owing to this structure, indirect interactions between factors can also be taken into consideration. Therefore, ANP is accepted as a more general form of AHP (Dinçer et al., 2019a,b,c; Reginauld et al., 2019). Abdel-Baset et al. (2019) identified the significant weights of the indicators that affect the selection of the best suppliers. DEMATEL is another MCDM method which aims to weight different factors. The main superiority of DEMATEL in comparison with AHP and ANP is that impact-relation map can be created (Zhang and Deng, 2019). With the help of this issue, the causal relationship between the factors can be defined (Chen et al., 2020b; Song et al., 2020). Jiang et al. (2020) tried to weight key performance indicators of hospital performance by using DEMATEL methodology. In addition, Singh and Sarkar (2020) found the important points in the product development for Indian automotive industry. Some of MCDM methods are also used to determine the most optimal alternatives. In this context, VIKOR is a frequently preferred approach in the literature. In this process, criteria are considered separately according to their benefits and costs (Kumar et al., 2020). Then, the most ideal result is determined (Hu et al., 2020a,b). Consequently, the alternative that is closest to the most ideal solution is defined as the best option (Gao et al., 2020). Another popular MCDM approach to rank the alternatives is TOPSIS. This method was preferred in the literature for various purposes, such as ranking suppliers (dos Santos et al., 2019; Memari et al., 2019). TOPSIS approach has many advantages over other techniques. For example, VIKOR method only considers the distance to the most ideal result. However, in TOPSIS, the distance to negative solution is also considered.

In the process of determining the important alternatives, first, there should be a certain set of criteria. In other words, these criteria lists are considered when choosing the best alternative. Within this context, the importance weights of the criteria can be considered equal. In addition, these significance weights can be determined based on the researcher's subjective assessment. It is obvious that both methods have some disadvantages (Nilashi et al., 2019). In this process, the most preferred issue is to consider MCDM methods in a hybrid way. In this context, primarily the criteria set is weighted with a method such as DEMATEL, AHP and ANP. After that, alternatives are also listed with approaches like TOPSIS and VIKOR. The main advantage of this situation is that more appropriate results can be reached due to the objective evaluation of the criteria (Zhang and Su, 2019; Petrovic and Kankaras, 2020). There are many studies in the literature that consider MCDM methods in a hybrid way. For instance, Ak and Gul (2019) considered both AHP and TOPSIS methods to evaluate the information security risks. On the other side, Bathaei et al. (2019) assessed green agility critical success factors by using ANP and VIKOR approached. Moreover, Zhu et al. (2020), Hu et al. (2020b) and Ma et al. (2019) used a hybrid combination of DEMATEL and VIKOR in their studies.

2.3. Decision making literature in energy investment

In this section, both MCDM in energy investments and fuzzy extensions of these models for this concept are detailed.

2.3.1. MCDM in energy investments

MCDM methods was preferred in the literature to evaluate the effectiveness of the energy investments. For instance, Wu et al. (2020) analyzed energy investments in 54 different countries by ANP method. They stated that the most important issue to be considered to make energy investments more effective is the political stability in the country. Similarly, Pérez-Velázquez et al. (2020) ranked different suppliers for photovoltaic module installation utilizing by using fuzzy VIKOR technique. Additionally, Rani et al. (2020) aimed to select the highest performance solar panel with this approach. Moreover, TOPSIS methodology is considered in evaluating the energy performance of European countries by Vavrek and Chovancová (2019a,b). Furthermore, Yazdani-Chamzini et al. (2013) aimed to select the optimal renewable energy alternatives. In this study, these alternatives are ranked by using VIKOR and MOORA approaches. Also, Bhowmik et al. (2019) made a comparative analysis by using different MCDM models to find the optimum green energy sources

2.3.2. MCDM fuzzy extensions in energy investment

Additionally, fuzzy logic was also considered with MCDM methods for the purpose of analyzing energy investments. For example, Dinçer et al. (2019a,b,c) evaluated European energy investment policies. In this study, balanced scorecard-based criteria are evaluated by using fuzzy AHP, fuzzy DEMATEL and fuzzy TOPSIS methods. Similarly, Qiu et al. (2020) made risk analysis for the wind energy investments in E7 economies. For this purpose, interval type-2 fuzzy DEMATEL, TOPSIS and VIKOR approaches are considered. Zhou and Qin (2020) considered the effectiveness of energy projects with fuzzy MCDM. In this study, they stated that the cost of energy investments should be considered in the effectiveness of these projects. Wang et al. (2020) calculated the weights of different criteria that affect the selection of renewable energy alternatives using the fuzzy AHP method. Moreover, Zhou and Qin (2020) aimed to evaluate sustainable energy investment policies by using DEMATEL and QUALIFLEX methods with the help of fuzzy logic.

2.4. The results of literature review

In the literature, the subject of energy investments was handled from different perspectives. An important part of these studies focused on factors that improve the efficiency of energy projects. Within this framework, the importance of issues such as technical competence, political stability, military and economic size, personnel competence and reserve quality were emphasized. However, it is seen that the studies focused on a limited number of variables in general. Therefore, in a new study, it would be correct to consider many variables that could affect the effectiveness of energy investments at the same time. In addition, it is thought that there is a need for studies on the use of large amounts of energy reserves that concern many different countries. In this way, it can be contributed to the efficient use of these energy resources among countries without any problems. In this study, an analysis will be carried out to make energy investments in the EMR effectively by different countries. Another issue that makes this study original is related to the methodology. In this study, hesitant IVIF DEMATEL and hesitant IVIF TOPSIS approaches will be considered for the first time for energy investments. Therefore, it is thought that the study will provide a methodological novelty.

3. Methodology

In this section, theoretical information regarding the methodology will be given. In this context, firstly, 2TLV and hesitant IVIF sets will be explained. After that, IVIF DEMATEL and IVIF TOPSIS approaches will be identified.

3.1. 2TLV and hesitant IVIF sets

Linguistic information is used in fuzzy sets with the aim of minimizing this problem in decision making. However, making exact evaluation is sometimes very difficult in this process. For this situation, the results of linguistic evaluation are provided in 2-tuples (S_i, a). In this context, a can take value between −0.5 and 0.5. Additionally, S gives information about the linguistic terms. On the other side, $\langle S\rangle$ explains the 2TLV and linguistic model can be shown as the functions of Δ and Δ^{-1}. The details are demonstrated on the Eqs. (1) and (2) (Ju et al., 2020).

$$\Delta(\beta) = (S_i, \alpha), \ \text{with} \begin{cases} i = round(\beta) \\ \alpha = \beta - i \end{cases} \tag{1}$$

$$\Delta^{-1} : \langle S\rangle \rightarrow [0, g] \ \text{and} \ \Delta^{-1}(S_i, \alpha) = i + \alpha \tag{2}$$

This evaluation can also be performed under the hesitancy. The main benefit of this situation is that it is very effective when there is not a consensus among the decision makers. Eq. (3) identifies the membership function.

$$S = \{S_0, S_1, \ldots, S_t\} \tag{3}$$

On the other side, context-free grammar can be defined in Eq. (4).

$$G_H = (V_N, V_T, I, P) \tag{4}$$

Additionally, hesitant linguistic fuzzy sets are defined as in Eq. (5).

$$h_S = \left\{S_i, S_{i+1}, \ldots, S_j\right\} \tag{5}$$

Moreover, Eq. (6) identifies the intuitionistic fuzzy set (I) whereas intuitionistic hesitant fuzzy set (H) is explained in Eq. (7). In these equations, μ is the element of $h_1(\vartheta)$ while n is the member of $h_2(\vartheta)$.

$$I = \{\langle\vartheta, \mu_I(\vartheta), n_I(\vartheta)\rangle / \vartheta \epsilon U\} \tag{6}$$

$$H = \{\langle\vartheta, h_1(\vartheta), h_2(\vartheta)\rangle, \vartheta \in U\} \tag{7}$$

In the final step, interval-valued intuitionistic hesitant fuzzy set ($\tilde{H}$) can be identified as in Eq. (8).

$$\tilde{H} = \left\{\left\langle\vartheta, h_{\tilde{H}}(\vartheta)\right\rangle, \vartheta \in U\right\} \tag{8}$$

3.2. IVIF DEMATEL

DEMATEL methodology aims to calculate which criteria are more important in decision making process. The biggest advantage of this model is generating impact relation map. Owing to this issue, the causality relationship between the items can be found. First, decision makers make their evaluations so that direct relation matrix ($\tilde{Z}$) is created. In this framework, average values of these evaluations are considered (Zhang et al., 2020). This process is given on the Eqs. (9) and (10).

$$\tilde{Z} = \begin{bmatrix} 0 & \tilde{z}_{12} & \cdots & \cdots & \tilde{z}_{1n} \\ \tilde{z}_{21} & 0 & \cdots & \cdots & \tilde{z}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1} & \tilde{z}_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{9}$$

$$\tilde{Z} = \frac{\tilde{Z}^1 + \tilde{Z}^2 + \tilde{Z}^3 + \cdots \tilde{Z}^n}{n} \tag{10}$$

In the next step, this matrix is normalized and Eqs. (11)–(13) are considered in this situation.

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \cdots & \tilde{x}_{nn} \end{bmatrix} \tag{11}$$

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{Z_{\acute{a}_{ij}}}{r}, \frac{Z_{\acute{b}_{ij}}}{r}\right), \left(\frac{Z_{\acute{c}_{ij}}}{r}, \frac{Z_{\acute{d}_{ij}}}{r}\right) \tag{12}$$

$$r = max\left(max_{1\leq i\leq n}\sum_{j=1}^{n} Z_{\acute{b}_{ij}}, max_{1\leq i\leq n}\sum_{j=1}^{n} Z_{\acute{b}_{ij}}\right) \tag{13}$$

After that, total relation matrix based on IVIF ($\widetilde{T}$) is calculated with the help of the Eqs. (14)–(18).

$$X_{\acute{a}} = \begin{bmatrix} 0 & a'_{12} & \cdots & \cdots & a'_{1n} \\ a'_{21} & 0 & \cdots & \cdots & a'_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a'_{n1} & a'_{n2} & \cdots & \cdots & 0 \end{bmatrix}, \ldots,$$

$$X_{\acute{d}} = \begin{bmatrix} 0 & d'_{12} & \cdots & \cdots & d'_{1n} \\ d'_{21} & 0 & \cdots & \cdots & d'_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ d'_{n1} & d'_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{14}$$

$$\tilde{T} = \lim_{k\to\infty} \tilde{X} + \tilde{X}^2 + \cdots + \tilde{X}^k \tag{15}$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & \cdots & \tilde{t}_{nn} \end{bmatrix} \quad (16)$$

$$\tilde{t}_{ij} = \left(\left(a''_{ij}, b''_{ij}\right), \left(c''_{ij}, d''_{ij}\right)\right) \quad (17)$$

$$\left[a''_{ij}\right] = X_{\acute{a}} \times (I - X_{\acute{a}})^{-1}, \ldots, \left[d''_{ij}\right] = X_{\acute{d}} \times \left(I - X_{\acute{d}}\right)^{-1} \quad (18)$$

Additionally, the sums of all vector rows and columns ($\tilde{D}_i$ and $\tilde{R}_i$) are calculated. The sum of these values can be considered to calculate the weights of the criteria. Moreover, the accuracy function $H(i)$ is also considered to employ the weights. Eqs. (19)–(21) are used in this process.

$$\tilde{D}_i = \left[\sum_{j=1}^{n} \tilde{t}_{ij}\right]_{n\times 1} \quad (19)$$

$$\tilde{R}_i = \left[\sum_{i=1}^{n} \tilde{t}_{ij}\right]'_{1\times n} \quad (20)$$

$$H(i) = \frac{a+b+c+d}{2} \quad (21)$$

3.3. IVIF TOPSIS

This model is used to compare the alternatives. In this process, weighted criteria are considered. In the calculation process, the negative and positive ideal solutions are considered at the same time. This situation is accepted as the main benefit of this approach. In the first step, the expert opinions are taken so that the decision matrix (D) based on IVIF sets can be calculated as in the Eqs. (22) and (23) (Garg and Kumar, 2020).

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} C1 & C2 & C3 & & \cdots & Cn \end{array} \\ \begin{bmatrix} h_{11} & h_{12} & h_{13} & \cdots & h_{1n} \\ h_{21} & h_{22} & h_{23} & \cdots & h_{2n} \\ h_{31} & h_{32} & h_{33} & \cdots & h_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ h_{m1} & h_{m2} & h_{m3} & \cdots & h_{mn} \end{bmatrix} \end{array} \quad (22)$$

$$h_{ij} = \frac{1}{k}\left[\sum_{e=1}^{n} h_{ij}{}^{e}\right], \ i = 1, 2, 3, \ldots, m \quad (23)$$

The weighted decision matrix is created in the next step. Within this context, the positive (A^+) and negative (A^-) values for the ideal solutions are identified as in Eq. (24).

$$A^+ = max\,(v_1, v_2, v_3, \ldots, v_n);\ A^- = min\,(v_1, v_2, v_3, \ldots, v_n) \quad (24)$$

In the next step, the closeness coefficient values (D^+ and D^-) are identified by considering the Eqs. (25) and (26).

$$D_i{}^+ = \sqrt{\sum_{i=1}^{m} (v_i - A_i{}^+)^2} \quad (25)$$

$$D_i{}^- = \sqrt{\sum_{i=1}^{m} (v_i - A_i{}^-)^2} \quad (26)$$

The final stage includes the ranking of alternatives. For this purpose, the closeness coefficient (CCi) is computed by using Eq. (27).

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (27)$$

4. Analysis

This section focuses on the evaluation for the effectiveness of energy investment projects in the EMR. In this study, it is aimed to find the important factors in the effectiveness of the energy investments. For this purpose, hesitant (IVIF) DEMATEL is considered based on 2-tuple linguistic values (2TLV). In the literature, there are lots of approaches which aim to weight the criteria, such as AHP and ANP. The main reason of selecting DEMATEL methodology is that it can create impact relation map for the criteria (Song et al., 2020). This situation provides an opportunity to make causality analysis for these factors (Roy et al., 2020a,b; Kaya and Yet, 2019). After that, hesitant TOPSIS method is used to evaluate these 8 countries with respect to the effectiveness in energy investments. For ranking different alternatives, VIKOR and MOORA are also popular MCDM techniques. However, TOPSIS methodology has some advantages over these approaches. In the analysis process, the distances to both positive and negative ideal solutions are considered (Alaa et al., 2019; Sharma et al., 2020). This situation contributes to reach more appropriate results (Suthar and Gadit, 2019). In the analysis process, both DEMATEL and TOPSIS methods are used based on 2-tuple hesitant IVIF sets. The main benefit of hesitant fuzzy sets is accepting similar opinions as common decisions (Hosseini and Kiani, 2019). This issue is quite beneficial when all decision makers do not have the same opinion (Zhang and Deng, 2019). Moreover, 2-tuple linguistic values provide more accurate fuzzification in the evaluation process (Gupta and Muhuri, 2017; Chen and Yeh, 2013). Additionally, this proposed model includes a hybrid MCDM methodology. In other words, two different MCDM techniques are considered in both weighting the criteria and ranking the alternatives. When the model is not hybrid, only one MCDM method is used with the aim of ranking the alternatives (Akincilar and Dagdeviren, 2014). In this framework, the weights of the criteria are considered by the authors subjectively (Chauhan and Singh, 2016). Hence, it is obvious that considering hybrid model provides more appropriate results because of making objective evaluations (Esteban et al., 2020). The details of this proposed model are illustrated on Fig. 1.

Fig. 1 illustrates that there are four different stages in the analysis process of this proposed model. In the first stage, the criteria, alternatives, and decision makers are defined. After that, IVIF sets are computed for both criteria and alternatives. Thirdly, the weights of the criteria are calculated. Finally, countries are ranked based on their performance.

4.1. Constructing criteria, alternatives and decision makers for MCDM Problem (Stage 1)

In this stage, firstly, the problem regarding energy investment is defined. After that, the determinants of the efficiency in these investments are selected. In the last step, the decision makers are identified for the evaluation of these criteria.

4.1.1. Step 1: Define the problem of energy investment projects

It is intended to measure the efficiency of energy investments in the EMR. The biggest reason for choosing this region is that according to the estimation of USGS, there are huge natural gas and oil reserves in this region. On the other hand, it is observed that there have been disagreements between the countries of the region, especially in the last days. Therefore, it is thought that appropriate strategies should be proposed for the efficient use of energy resources in this region. Within this context, MCDM methods can be very helpful to find optimal solutions to increase the efficiency in these investments.

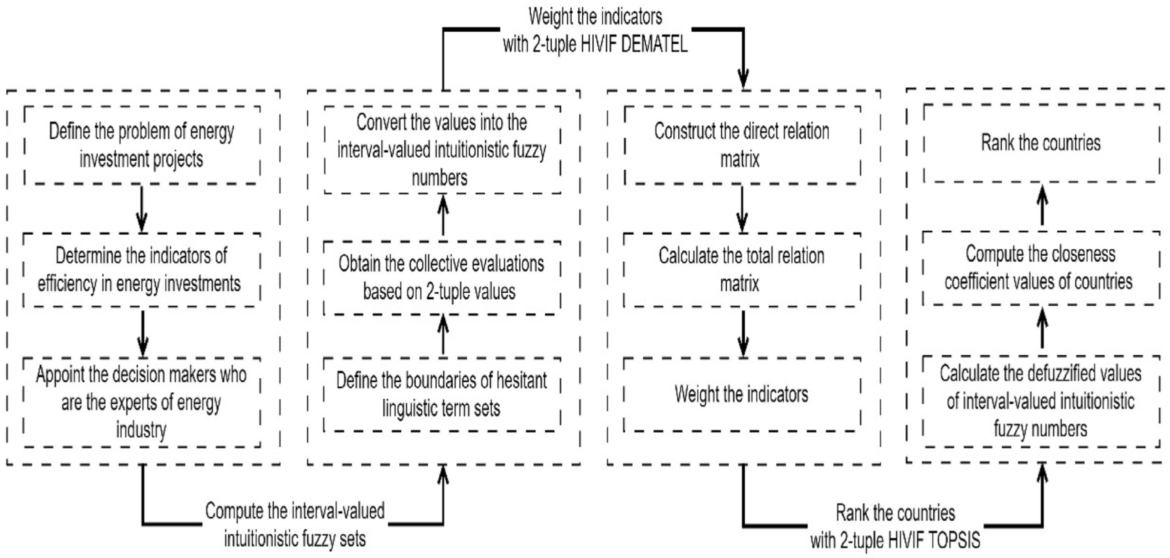

Fig. 1. The Details of the Proposed Model.

Table 1
Indicators of the efficiency in energy investment projects.

Efficiency Indicators	Supported Literature
Political Stability - C(1)	Boute (2020), Wu et al. (2020) and Franza et al. (2020)
Cost - C(2)	Majid (2020) and Salehi et al. (2020)
Distribution - C(3)	Zhang (2020) and Laguna-Martinez et al. (2020)
Technological Capacity - C(4)	McCabe (2020), Hu et al. (2020a,b) and Zhou and Qin (2020)
Reserve Quality - C(5)	Qadrdan et al. (2020) and Gorre et al. (2020)
Military Power - C(6)	Smith and Gülen (2020) and Meyer (2020)
Reserve Amount - C(7)	Qiu (2020), Nyambuu and Semmler (2020)
Economic Power - C(8)	Anton and Nucu (2020) and Ahmad et al. (2020)
Employee Competency - C(9)	Mahama et al. (2020) and Kealy (2020)

4.1.2. Step 2: Determining the indicators of efficiency in energy investments

In this step, the criteria related to the effectiveness of energy investments have been determined. Details of these items are stated in Table 1.

Table 1 shows 9 different criteria that affect the efficiency of energy investments. These criteria have an important role in increasing the efficiency of energy resources in the EMR. Due to the high estimated amount of energy resources in this region, there have been some difficulties among the countries. Therefore, political stability (C(1)) is important in the effectiveness of this process. For example, the internal conflict in Libya and political tensions between Turkey and Greece has a preventing role on the effective usage of the energy sources. Cost of energy projects (C(2)) can also have an influence for this issue. It is estimated that a significant size of the energy reserves in this region is miles under the sea. Hence, the cost of extracting these reserves to the ground will be very high. In this context, countries that can supply these energy reserves at the lowest cost will gain an important advantage compared to others. On the other hand, how the distribution (C(3)) of these energy resources to other countries will be is another important issue. However, the transmission of these reserves from the EMR to Europe is both difficult and costly. Therefore, countries that have an energy route will have an advantage.

In addition, the difficulty of both providing energy resources in the region and distributing these energies to other countries shows the importance of the technical competence (C(4)). Therefore, countries that are especially competent in engineering will have an advantage in this process. Moreover, the quality of energy reserves (C(5)) in the EMR is also essential in the effectiveness of these investment projects. If these reserves are of poor quality, the sales revenue will be very low. This will decrease the efficiency of energy investments in the region. Furthermore, the companies that conduct energy exploration activities in the EMR can be protected by the navies of those countries. The main reason is the political uncertainties between countries. Countries with high military power (C(6)) will have more voice in disputes in the region. This will naturally cause these countries to be more successful in energy investment projects.

On the other hand, the amount of energy reserves (C(7)) for the continental shelf of the countries in the region will also affect the efficiency of these investments. It is very costly to extract energy resources from under the sea to the earth and distribute these resources to other countries. Therefore, when the amount of the energy reserves is high, it has a positive influence on the efficiency of these investments. In addition, another factor affecting the effectiveness of these countries regarding the energy investment projects is their economic power (C(8)). Countries that are economically vulnerable may be less active in the region. Furthermore, personnel competence (C(9)) can play also a key role for the efficiency of energy investments. Countries should have a great deal of engineering knowledge to provide energy resources especially in the EMR. In this framework, countries that have employed competent staff will gain an important advantage compared to others.

4.1.3. Step 3: Appoint the Decision Makers Who are the Experts of Energy Industry

These 9 different criteria are examined according to their significance in the effectiveness of energy investments in the EMR. In this process, the evaluations of 3 different experts are

Table 2
The details of the experts.

Experts	Level of education	Experience	Occupation	Areas of Expertise
Expert 1	PhD	19 years	Academician and top-level manager in energy companies	Cost management, energy investment
Expert 2	PhD	15 years	Academician and middle-level manager in energy companies	Energy investment, strategy development
Expert 3	PhD	22 years	Academician in energy investment	Energy economics, energy investment

Table 3
Linguistic scales and numbers.

Criteria	Alternatives	Evaluation Numbers
No influence (n)	Worst (w)	1
somewhat influence (s)	Poor (p)	2
medium influence (m)	Fair (f)	3
high influence (h)	Good (g)	4
very high influence (vh)	Best (b)	5

Table 4
DRM for criteria.

Criteria	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	C(7)	C(8)	C(9)
C(1)	.00	1.37	.77	.77	1.27	.93	1.13	.93	.77
C(2)	.35	.00	.73	.62	.65	.65	.80	.36	.45
C(3)	.38	.73	.00	.80	1.20	.80	1.17	.62	.55
C(4)	.42	.73	.77	.00	1.20	.70	1.10	.73	.73
C(5)	.23	.35	.38	.12	.00	.57	.55	.35	.45
C(6)	.21	.29	.42	.53	.56	.00	.65	.80	.60
C(7)	.18	.38	.38	.35	.45	.45	.00	.30	.30
C(8)	.29	.29	.45	.45	.56	.45	.62	.00	.53
C(9)	.35	.29	.36	.49	.56	.65	.62	.53	.00

Table 5
Normalized DRM.

Criteria	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	C(7)	C(8)	C(9)
C(1)	.00	.17	.10	.10	.16	.12	.14	.12	.10
C(2)	.04	.00	.09	.08	.08	.08	.10	.05	.06
C(3)	.05	.09	.00	.10	.15	.10	.15	.08	.07
C(4)	.05	.09	.10	.00	.15	.09	.14	.09	.09
C(5)	.03	.04	.05	.01	.00	.07	.07	.04	.06
C(6)	.03	.04	.05	.07	.07	.00	.08	.10	.08
C(7)	.02	.05	.05	.04	.06	.06	.00	.04	.04
C(8)	.04	.04	.06	.06	.07	.06	.08	.00	.07
C(9)	.04	.04	.05	.06	.07	.08	.08	.07	.00

applied. These experts are at least mid-level managers with minimum 15 years of experience in international energy investment projects. The details of the experts are given on Table 2.

Table 2 gives information that the experts have enough qualifications to evaluate the criteria for the effectiveness of the energy investments.

4.2. Computing the IVIF Sets (Stage 2)

In the next stage, the experts made evaluations regarding these criteria. In this evaluation process, the linguistic scales and numbers will be used for both criteria and alternatives as in Table 3. These scales were considered in many different studies in the literature (Abdullah and Rahim, 2019; Abdullah and Zulkifli, 2019; Abdullah and Rahim, 2019; Dinçer et al., 2019a,b,c).

In this framework, the limits are defined for the evaluations under the hesitancy. After that, 2TLVs are defined regarding the linguistic evaluations for both criteria and alternatives. Finally, IVIF sets are calculated for these factors.

4.2.1. Step 1: Defining the Boundaries of Hesitant Linguistic Term Sets

In this framework, firstly, the boundaries for alternatives are identified. These details are demonstrated on Tables A.1 and A.4 in the appendix part.

Table 6
TRM.

Criteria	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	C(7)	C(8)	C(9)
C(1)	.08	.28	.22	.21	.33	.27	.33	.24	.22
C(2)	.09	.08	.17	.15	.19	.17	.21	.13	.14
C(3)	.11	.18	.10	.19	.28	.22	.29	.18	.17
C(4)	.11	.19	.19	.10	.29	.21	.28	.20	.19
C(5)	.06	.09	.10	.07	.07	.13	.14	.10	.11
C(6)	.07	.10	.12	.13	.16	.08	.18	.17	.14
C(7)	.05	.09	.10	.09	.13	.11	.07	.09	.09
C(8)	.07	.10	.12	.11	.16	.13	.17	.07	.13
C(9)	.08	.10	.11	.12	.16	.16	.17	.13	.07

Table 7
Weights of criteria.

Criteria	D	E	D+E	D-E	Weights
Political Stability (C(1))	2.182	0.712	2.893	1.470	0.121
Cost (C(2))	1.328	1.217	2.546	0.111	0.107
Distribution (C(3))	1.716	1.213	2.929	0.503	0.123
Technological Capacity (C(4))	1.751	1.163	2.914	0.587	0.122
Reserve Quality (C(5))	0.857	1.7726	2.629	−0.916	0.110
Military Power (C(6))	1.142	1.4715	2.614	−0.329	0.109
Reserve Amount (C(7))	0.819	1.8423	2.661	−1.023	0.111
Economic Power (C(8))	1.048	1.3039	2.352	−0.256	0.098
Employee Competency (C(9))	1.104	1.2511	2.355	−0.147	0.099

Table 8
Decision matrix with accuracy function.

Alternatives	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	C(7)	C(8)	C(9)
A1	.358	.467	.450	.533	.500	.417	.533	.417	.567
A2	.700	.700	.767	.667	.667	.450	.667	.733	.933
A3	.800	.800	.767	.733	.800	1.067	.733	1.100	1.333
A4	1.233	1.333	1.233	1.367	1.133	1.233	1.333	1.333	1.267
A5	.417	.667	.417	.492	.533	.583	.450	.450	.533
A6	.417	.533	.417	.417	.300	.350	.533	.383	.450
A7	.358	.450	.417	.417	.208	.208	.417	.300	.267
A8	.833	.833	1.133	.967	1.000	1.133	1.167	1.267	1.233

Table 9
The Values of D+, D- and CCi.

Countries	D+	D-	CC_i
(A1)	0.809	0.139	0.147
(A2)	0.585	0.362	0.382
(A3)	0.364	0.584	0.616
(A4)	0.009	0.939	0.991
(A5)	0.774	0.174	0.183
(A6)	0.860	0.087	0.092
(A7)	0.948	0.000	0.000
(A8)	0.213	0.735	0.775

Table 10
Ranking results of alternatives.

Countries	Ranking
Cyprus (A1)	6
Egypt (A2)	4
Greece (A3)	3
Israel (A4)	1
Lebanon (A5)	5
Libya (A6)	7
Syria (A7)	8
Turkey (A8)	2

Table A.1
Limits of evaluations under hesitancy.

	C(1)			C(2)			C(3)			C(4)			C(5)		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
C(1)				(vh, vh)	(vh, vh)	(h, vh)	(m,h)	(h,h)	(n,h)	(m,h)	(m,m)	(m,h)	(vh, vh)	(vh, vh)	(h,vh)
C(2)	(n,s)	(s,m)	(s,s)		l		(n,m)	(h,h)	(m,h)	(n,h)	(n,m)	(h,h)	(s,h)	(s,h)	(s,h)
C(3)	(s,m)	(s,s)	(n,m)	(m,vh)	(m,m)	(n,h)				(m,h)	(m,h)	(m,h)	(h, vh)	(h, vh)	(h, vh)
C(4)	(s,h)	(m,m)	(n,m)	(h, vh)	(h,h)	(h,h)	(m,vh)	(n,m)	(h,h)				(h, vh)	(h, vh)	(h, vh)
C(5)	(s,s)	(s,s)	(s,s)	(s,m)	(s,m)	(s,s)	(n,m)	(n,s)	(m,m)	(s,s)	(n,n)	(n,n)			
C(6)	(s,s)	(n,m)	(s,s)	(s,m)	(n,m)	(s,m)	(s,m)	(s,m)	(s,s)	(s,s)	(m,m)	(m,m)	(s,h)	(n,h)	(n,h)
C(7)	(s,s)	(n,s)	(s,b)	(s,m)	(m,m)	(s,m)	(s,s)	(s,m)	(s,s)	(s,s)	(s,m)	(n,s)	(s,m)	(s,m)	(s,m)
C(8)	(s,m)	(n,m)	(s,m)	(s,m)	(n,m)	(m,m)	(s,m)	(s,m)	(s,m)	(s,m)	(n,m)	(m,m)	(s,h)	(n,h)	(n,h)
C(9)	(s,m)	(s,m)	(s,m)	(s,m)	(n,m)	(s,m)	(s,m)	(n,m)	(n,m)	(s,m)	(n,m)	(n,h)	(s,h)	(n,h)	(n,h)

	C(6)			C(7)			C(8)			C(9)		
	1	2	3	1	2	3	1	2	3	1	2	3
C(1)	(s,h)	(h,h)	(h,h)	(vh,vh)	(vh,vh)	(n,h)	(s,h)	(h,h)	(m,vh)	(s,h)	(m,m)	(m,vh)
C(2)	(s,h)	(s,h)	(s,h)	(m,h)	(m,h)	(m,h)	(s,m)	(n,m)	(n,m)	(s,m)	(n,m)	(m,m)
C(3)	(m,h)	(m,h)	(m,h)	(h,vh)	(h,vh)	(m,vh)	(s,h)	(s,h)	(s,m)	(s,m)	(s,h)	(n,m)
C(4)	(m,h)	(m,h)	(n,m)	(h,vh)	(h,vh)	(m,m)	(m,h)	(m,h)	(s,m)	(s,h)	(n,h)	(h,h)
C(5)	(s,m)	(m,m)	(m,m)	(n,h)	(m,m)	(n,m)	(s,m)	(n,s)	(s,s)	(s,m)	(s,m)	(s,m)
C(6)				(n,h)	(n,h)	(h,h)	(m,h)	(m,h)	(m,h)	(m,m)	(m,m)	(m,m)
C(7)	(s,m)	(s,m)	(s,m)				(s,s)	(s,s)	(s,s)	(s,s)	(s,s)	(s,s)
C(8)	(s,m)	(s,m)	(s,m)	(s,h)	(n,h)	(m,m)				(s,m)	(s,m)	(m,m)
C(9)	(s,h)	(s,h)	(s,h)	(s,h)	(n,h)	(m,m)	(s,m)	(s,m)	(m,m)			

Table A.2
2TLV of collective linguistic evaluations for criteria.

	C(1)		C(2)		C(3)		C(4)		C(5)	
	O	P	O	P	O	P	O	P	O	P
C(1)			(vh,0)	(vh,-.33)	(m,0)	(m,-.33)	(h,-.33)	(m,0)	(vh,0)	(vh,-.33)
C(2)	(s,.33)	(s,-.33)			(m,-.33)	(m,-.33)	(h,-.33)	(s,0)	(h,0)	(s,0)
C(3)	(m,-.33)	(s,-.33)	(h,0)	(s,.33)			(h,0)	(m,0)	(vh,0)	(vh,0)
C(4)	(m,-.33)	(s,0)	(m,.33)	(m,0)	(h,0)	(m,-.33)			(vh,0)	(vh,0)
C(5)	(s,-.33)	(s,-.33)	(s,.33)	(s,-.33)	(m,-.33)	(s,-.33)	(n,.33)	(n,.33)		
C(6)	(s,0)	(n,.33)	(s,.33)	(n,.33)	(m,-.33)	(s,0)	(m,-.33)	(m,-.33)	(h,0)	(n,.33)
C(7)	(s,-.33)	(n,.33)	(s,.33)	(s,0)	(s,.33)	(s,0)	(s,.33)	(s,-.33)	(m,0)	(s,0)
C(8)	(s,.33)	(n,.33)	(s,.33)	(n,.33)	(m,0)	(s,0)	(m,0)	(s,0)	(h,0)	(n,.33)
C(9)	(s,.33)	(s,-.33)	(s,.33)	(n,.33)	(m,0)	(n,.33)	(m,.33)	(n,.33)	(h,0)	(n,.33)

	C(6)		C(7)		C(8)		C(9)	
	O	P	O	P	O	P	O	P
C(1)	(h,0)	(m,.33)	(vh,-.33)	(h,-.33)	(h,.33)	(m,0)	(h,0)	(m,-.33)
C(2)	(h,0)	(s,0)	(h,0)	(m,0)	(m,0)	(n,.33)	(m,0)	(s,0)
C(3)	(h,0)	(m,0)	(vh,0)	(h,-.33)	(h,-.33)	(s,0)	(m,.33)	(s,-.33)
C(4)	(h,-.33)	(s,.33)	(h,.33)	(h,-.33)	(h,-.33)	(m,-.33)	(h,0)	(s,.33)
C(5)	(m,0)	(m,-.33)	(m,.33)	(s,-.33)	(s,.33)	(s,-.33)	(m,0)	(s,0)
C(6)			(h,0)	(s,0)	(h,0)	(m,0)	(m,0)	(m,-.33)
C(7)	(m,0)	(s,0)			(s,0)	(s,0)	(s,0)	(s,-.33)
C(8)	(m,0)	(s,0)	(h,-.33)	(s,0)			(m,0)	(s,0)
C(9)	(h,0)	(s,0)	(h,-.33)	(s,0)	(m,0)	(s,.33)		

*O: Optimistic; P: Pessimistic.

4.2.2. Step 2: Obtaining the Collective Evaluations based on 2-tuple Values

After that, these values are converted to 2TLV of collective linguistic evaluations for both criteria and alternatives. These issues are indicated on Tables A.2 and A.5

4.2.3. Step 3: Converting the Values into the IVIF Numbers

In the final phase, IVIF sets for the criteria and alternatives can be defined. This process is illustrated on Tables A.3 and A.6.

4.3. Weighting the indicators with 2-tuple HIVIF DEMATEL (Stage 3)

This stage aims to find the significance values of the criteria. Within this context, direct relation matrix (DRM), normalized matrix and total relation matrix (TRM) are generated, respectively. While considering these matrixes, the weights of the indicators are calculated.

4.3.1. Step 1: Constructing the Direct Relation Matrix

In this step, the DRM can be generated for the criteria which is given in Table 4. For this purpose, the Eqs. (9) and (10) are taken into consideration.

4.3.2. Step 2: Calculating the Total Relation Matrix

After creating DRM, the normalization process is occurred for these values with the help of the Eqs. (11)–(13). This normalized matrix is stated on Table 5.

Moreover, TRM is generated by considering the Eqs. (14)–(18). The details of this matrix are stated on Table 6.

4.3.3. Step 3: Weighting the Indicators

In the final step, the weights of these 9 criteria are identified. The analysis results are shown in Table 7. In this context, the Eqs. (19)–(21) are taken into consideration.

Table 7 indicates that the distribution is the most important criterion regarding the effectiveness in energy investment. Similarly, political stability and technological capacity also play significant role for this condition. Nonetheless, it is also determined that economic power, employee competency and cost have the lowest weights.

4.4. Ranking the countries with 2-tuple HIVIF TOPSIS (Stage 4)

Finally, these 8 countries are compared for the performance in energy investments by using hesitant IVIF TOPSIS method based on 2TLV. Within this scope, firstly, the defuzzified values of IVIF numbers are calculated. Next, the closeness coefficient values are defined. By considering them, the countries can be ranked.

4.4.1. Step 1: Computing the Defuzzified Values of IVIF Numbers

Firstly, the defuzzified values of decision matrix are created with the accuracy function. Table 8 explains the details of this matrix.

4.4.2. Step 2: Computing the Closeness Coefficient Values of the Countries

After that, D+, D- and CC_i values are computed with the help of the Eqs. (25)–(27). The details of these values are given on Table 9.

4.4.3. Step 3: Ranking the Countries

In the final stage, these 8 countries are ranked. The analysis results are demonstrated on Table 10.

Table 10 gives information that Israel and Turkey are the most successful countries with respect to the energy investment in EMR. Similarly, it is also defined that Greece and Egypt are other successful countries in this region. Nevertheless, another important conclusion is that Cyprus, Libya, and Syria are the worst countries.

5. Conclusion and policy implications

This study identifies the indicators that have an influence on the effectiveness of countries in energy investments. Within this scope, 8 different countries with continental shelf in the EMR are considered. For this purpose, 9 different criteria are selected based on the literature review. The significance levels of them are calculated by considering IVIF DEMATEL based on 2TLV. It is identified that the distribution, political stability, and technological capacity are the most important factors for the effectiveness in energy investment. On the other side, it is also concluded that economic power, employee competency and cost have the lowest weights.

Table A.3
IVIF sets for criteria.

	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	C(7)	C(8)	C(9)
C(1)		((.60,.80), (.60,.73))	((.40,.60), (.20,.33))	((.40,.53), (.20,.40))	((.60,.80), (.40,.73))	((.40,.60), (.40,.47))	((.60,.73), (.40,.53))	((.60,.67), (.20,.40))	((.40,.60), (.20,.33))
C(2)	((.20,.27), (.10,.13))		((.40,.53), (.20,.33))	((.40,.53), (.10,.20))	((.40,.60), (.10,.20))	((.40,.60), (.10,.20))	((.40,.60), (.20,.40))	((.20,.40), (.05,.07))	((.20,.40), (.10,.20))
C(3)	((.20,.33), (.10,.13))	((.40,.60), (.20,.27))		((.40,.60), (.20,.40))	((.60,.80), (.40,.60))	((.40,.60), (.20,.40))	((.60,.80), (.40,.53))	((.40,.53), (.10,.20))	((.40,.47), (.10,.13))
C(4)	((.20,.33), (.10,.20))	((.40,.47), (.20,.40))	((.40,.60), (.20,.33))		((.60,.80), (.40,.60))	((.40,.53), (.20,.27))	((.60,.67), (.40,.53))	((.40,.53), (.20,.33))	((.40,.60), (.20,.27))
C(5)	((.10,.13), (.10,.13))	((.20,.27), (.10,.13))	((.20,.33), (.10,.13))	((.05,.07), (.05,.07))		((.20,.40), (.20,.33))	((.40,.47), (.10,.13))	((.20,.27), (.10,.13))	((.20,.40), (.10,.20))
C(6)	((.10,.20), (.05,.07))	((.20,.27), (.05,.07))	((.20,.33), (.10,.20))	((.20,.33), (.20,.33))	((.40,.60), (.05,.07))		((.40,.60), (.10,.20))	((.40,.60), (.20,.40))	((.20,.40), (.20,.40))
C(7)	((.10,.13), (.05,.07))	((.20,.27), (.10,.20))	((.20,.27), (.10,.20))	((.20,.27), (.10,.13))	((.20,.40), (.10,.20))	((.20,.40), (.10,.20))		((.10,.20), (.10,.20))	((.10,.20), (.10,.20))
C(8)	((.20,.27), (.05,.07))	((.20,.27), (.05,.07))	((.20,.40), (.10,.20))	((.20,.40), (.10,.20))	((.40,.60), (.05,.07))	((.20,.40), (.10,.20))	((.40,.53), (.10,.20))		((.20,.40), (.20,.27))
C(9)	((.20,.27), (.10,.13))	((.20,.27), (.05,.07))	((.20,.40), (.05,.07))	((.40,.47), (.05,.07))	((.40,.60), (.05,.07))	((.40,.60), (.10,.20))	((.40,.53), (.10,.20))	((.20,.40), (.20,.27))	

Table A.4
Boundaries of hesitant linguistic term sets for alternatives.

	C(1)			C(2)			C(3)			C(4)			C(5)		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
A1	(poor,fair)	(worst,fair)	(worst,fair)	(fair,fair)	(poor,poor)	(poor,poor)	(poor,fair)	(worst,fair)	(fair,fair)	(worst,fair)	(fair,fair)	(fair,fair)	(fair,fair)	(poor,fair)	(poor,poor)
A2	(fair,best)	(fair,fair)	(worst,fair)	(fair,fair)	(poor,good)	(poor,good)	(fair,best)	(fair,fair)	(fair,fair)	(worst,good)	(fair,fair)	(fair,fair)	(poor,fair)	(fair,good)	(poor,fair)
A3	(good,best)	(fair,best)	(worst,fair)	(fair,best)	(fair,good)	(fair,fair)	(fair,fair)	(fair,good)	(fair,good)	(fair,good)	(fair,fair)	(fair,fair)	(fair,best)	(fair,fair)	(fair,good)
A4	(good,best)	(best,best)	(good,best)	(good,best)	(best,best)	(good,best)	(good,best)	(good,best)	(best,best)	(best,best)	(good,best)	(best,best)	(good,best)	(best,best)	(good,best)
A5	(fair,fair)	(poor,fair)	(worst,poor)	(fair,good)	(poor,fair)	(poor,fair)	(fair,fair)	(worst,fair)	(worst,fair)	(poor,good)	(worst,fair)	(worst,fair)	(fair,fair)	(fair,fair)	(worst,fair)
A6	(poor,poor)	(worst,poor)	(poor,poor)	(fair,fair)	(worst,fair)	(fair,fair)	(poor,fair)	(poor,fair)	(poor,poor)	(poor,poor)	(worst,fair)	(fair,fair)	(poor,poor)	(poor,poor)	(poor,poor)
A7	(poor,poor)	(worst,poor)	(worst,poor)	(poor,fair)	(poor,fair)	(poor,fair)	(poor,fair)	(poor,fair)	(poor,poor)	(good,fair)	(poor,fair)	(poor,poor)	(worst,poor)	(worst,poor)	(poor,poor)
A8	(good,best)	(good,good)	(worst,good)	(good,good)	(good,best)	(worst,best)	(good,best)	(good,good)	(good,good)	(good,good)	(good,good)	(fair,good)	(good,good)	(good,best)	(fair,good)

	C(6)			C(7)			C(8)			C(9)		
	1	2	3	1	2	3	1	2	3	1	2	3
A1	(fair,fair)	(worst,fair)	(poor,poor)	(fair,fair)	(fair,fair)	(worst,fair)	(fair,fair)	(worst,fair)	(poor,poor)	(poor,fair)	(fair,fair)	(fair,fair)
A2	(poor,fair)	(poor,fair)	(poor,fair)	(fair,good)	(poor,fair)	(poor,fair)	(fair,good)	(fair,fair)	(fair,fair)	(good,good)	(good,good)	(fair,fair)
A3	(fair,best)	(good,best)	(fair,fair)	(fair,best)	(fair,fair)	(poor,fair)	(good,best)	(good,best)	(fair,fair)	(best,best)	(best,best)	(good,good)
A4	(good,best)	(best,best)	(good,best)	(best,best)	(good,best)	(good,best)	(best,best)	(good,best)	(good,best)	(best,best)	(good,best)	(best,best)
A5	(poor,fair)	(poor,good)	(poor,fair)	(poor,fair)	(worst,fair)	(fair,fair)	(poor,fair)	(worst,fair)	(fair,fair)	(fair,fair)	(poor,fair)	(poor,fair)
A6	(worst,fair)	(poor,poor)	(poor,poor)	(poor,poor)	(fair,fair)	(fair,fair)	(poor,fair)	(poor,poor)	(poor,poor)	(poor,fair)	(poor,fair)	(poor,fair)
A7	(poor,poor)	(worst,poor)	(worst,poor)	(poor,fair)	(poor,fair)	(poor,poor)	(poor,poor)	(poor,poor)	(poor,poor)	(poor,poor)	(poor,poor)	(worst,poor)
A8	(good,good)	(good,best)	(good,good)	(good,good)	(good,best)	(good,best)	(best,best)	(good,good)	(good,good)	(best,best)	(good,good)	(best,best)

Table A.5
2TLV of collective linguistic evaluations for alternatives.

	C1		C2		C3		C4		C5	
	O	P	O	P	O	P	O	P	O	P
A1	(f,0)	(w,.33)	(p,.33)	(p,.33)	(f,0)	(p,0)	(f,0)	(p,.33)	(f,-.33)	(p,.33)
A2	(g,-.33)	(p,.33)	(g,-.33)	(p,.33)	(g,-.33)	(f,0)	(f,.33)	(p,.33)	(f,.33)	(p,.33)
A3	(g,.33)	(f,-.33)	(g,0)	(f,0)	(g,-.33)	(f,0)	(f,.33)	(f,0)	(g,0)	(f,0)
A4	(b,0)	(g,.33)	(b,0)	(g,.33)	(b,0)	(g,.33)	(b,0)	(b,-.33)	(g,0)	(g,.33)
A5	(f,-.33)	(p,0)	(f,.33)	(p,.33)	(f,0)	(p,-.33)	(f,.33)	(w,.33)	(f,0)	(p,.33)
A6	(p,0)	(p,-.33)	(f,0)	(p,.33)	(f,-.33)	(p,0)	(f,-.33)	(p,0)	(p,0)	(p,0)
A7	(p,0)	(w,.33)	(f,0)	(p,0)	(f,-.33)	(p,0)	(f,-.33)	(p,0)	(p,0)	(w,.33)
A8	(g,.33)	(f,0)	(g,.33)	(f,0)	(g,.33)	(g,0)	(g,0)	(g,-.33)	(g,.33)	(g,-.33)

	C6		C7		C8		C9	
	O	P	O	P	O	P	O	P
A1	(f,-.33)	(p,0)	(f,0)	(p,.33)	(f,-.33)	(p,0)	(f,0)	(f,-.33)
A2	(f,0)	(p,0)	(f,.33)	(p,.33)	(f,.33)	(f,0)	(g,-.33)	(g,-.33)
A3	(g,.33)	(f,.33)	(g,-.33)	(f,-.33)	(g,.33)	(g,-.33)	(b,-.33)	(b,-.33)
A4	(b,0)	(g,.33)	(b,0)	(g,.33)	(b,0)	(g,.33)	(b,0)	(b,-.33)
A5	(f,.33)	(p,0)	(f,0)	(p,0)	(f,0)	(p,0)	(f,0)	(p,.33)
A6	(p,.33)	(p,-.33)	(f,-.33)	(f,-.33)	(p,.33)	(p,0)	(f,0)	(p,0)
A7	(p,0)	(w,.33)	(f,-.33)	(p,0)	(p,0)	(p,0)	(p,0)	(p,-.33)
A8	(g,.33)	(g,0)	(b,-.33)	(g,0)	(g,.33)	(g,.33)	(b,-.33)	(b,-.33)

*O: Optimistic; P: Pessimistic.

One of the most important factors contributing the success in energy investments in the EMR is the distribution of energy. In this framework, countries with efficient distribution lines will be able to manage their investments more effectively in this process. A significant majority of the energy reserves in the EMR are under the sea. Hence, to transfer these reserves provided by the countries to other countries, an effective pipeline must be available. Within this context, countries that want to effectively evaluate their energy investments in this region should first give importance to energy routes. Accordingly, countries should establish routes for target markets. Another important issue here is the partnership with the countries that already have an effective route. Otherwise, even if they have excess reserves, countries will not be able to transfer this energy to the target audience easily and the cost of these investments will increase too much. This result has been emphasized by many researchers in the literature. For example, Zhang (2020) investigated renewable energy investments in China. In this study, it is identified that to improve the effectiveness in energy investments, distribution network is quite essential. Similarly, Laguna-Martinez et al. (2020) also examined the energy investments in Mexico. By using the mathematical modeling methodology, it is stated that energy investments will be more successful if there is an efficient distribution.

Another result is that political stability plays a crucial role in the effectiveness of energy investments in the countries of the EMR. Energy reserves in this region have a very serious economic size. Thus, political tensions may occur between countries in the process of using energy resources in this region. In this process, countries with political stability will have an important advantage. Otherwise, if there is no stability in the management of countries, countries will not be able to implement an effective energy policy. Within this context, especially countries in this region should pay attention to political stability. Therefore, the governments of these countries should identify possible problems within the country and take the necessary actions on time. Hence, it can be very much easier for countries to continue their energy investment policies effectively.

The importance of the political stability was also identified in many different studies. For instance, Wu et al. (2020) focused on the risk assessment in the renewable energy investments. For this purpose, an analysis was conducted for China by using ANP methodology. It is concluded that political stability is one of the most significant issues that should be taken into consideration for the effectiveness of the energy investment. Parallel to this study, Boute (2020) made a study to understand the relationship between political stability and renewable energy investments. Within this context, recent years of Kazakhstan are considered, and it is identified that to increase the effectiveness in renewable energy investments, there should be political stability in the country. Also, Franza et al. (2020) made an evaluation for Southern and East Mediterranean (SEMED) countries and underlined the importance of the same result.

Technological factors are another prominent issue in the efficiency of energy investments in the EMR. Since the energy resources in this region are under the sea, it is difficult to extract these energy resources. In other words, serious engineering knowledge is required to use these energy reserves. Countries with insufficient technological infrastructure will have difficulty using these reserves even if they have them. This situation will prevent the efficient use of these energy resources. Therefore, countries with energy reserves in the EMR should make the necessary investments to improve their technological infrastructure. Within this framework, countries must have seismic exploration and drilling vessels necessary to locate these energy reserves and to supply these energies.

Lots of the researchers in the literature supported this argument. As an example, McCabe (2020) aimed to evaluate the major producers of crude oil and natural gas. They identified that countries must have technological power for the energy investment company to be effective. Similarly, Hu et al. (2020a,b) also conducted a study to evaluate energy projects in the USA. In this study, regression and cointegration methods are considered. They argued that energy investments cannot be effective if the company is not technologically sufficient. They also underlined that energy investments projects contain serious engineering knowledge. Moreover, Zhou and Qin (2020) evaluated energy projects in China by using different methodology. They reached a conclusion that the technological infrastructure is very significant for the success of energy projects.

In this study, finally, 8 different countries with continental shelf in the region are evaluated with respect to the effectiveness in energy investments. For this purpose, hesitant IVIF TOPSIS method is taken into consideration based on 2TLV. It is determined that Israel and Turkey are the most successful countries

Table A.6
IVIF sets for alternatives.

	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	C(7)	C(8)	C(9)
A1	((.20,.40), (.05,.07))	((.20,.27), (.20,.27))	((.20,.40), (.10,.20))	((.20,.40), (.20,.27))	((.20,.33), (.20,.27))	((.20,.33), (.10,.20))	((.20,.40), (.20,.27))	((.20,.33), (.10,.20))	((.20,.40), (.20,.33))
A2	((.40,.53), (.20,.27))	((.40,.53), (.20,.27))	((.40,.53), (.20,.40))	((.40,.47), (.20,.27))	((.40,.47), (.20,.27))	((.20,.40), (.10,.20))	((.40,.47), (.20,.27))	((.40,.47), (.20,.40))	((.40,.53), (.40,.53))
A3	((.40,.67), (.20,.33))	((.40,.60), (.20,.40))	((.40,.53), (.20,.40))	((.40,.47), (.20,.40))	((.40,.60), (.20,.40))	((.60,.67), (.40,.47))	((.40,.53), (.20,.33))	((.60,.67), (.40,.53))	((.60,.73), (.60,.73))
A4	((.40,.80), (.60,.67))	((.60,.80), (.60,.67))	((.60,.80), (.40,.67))	((.60,.80), (.60,.73))	((.40,.60), (.60,.67))	((.40,.80), (.60,.67))	((.60,.80), (.60,.67))	((.60,.80), (.60,.67))	((.40,.80), (.60,.73))
A5	((.20,.33), (.10,.20))	((.40,.47), (.20,.27))	((.20,.40), (.10,.13))	((.40,.47), (.05,.07))	((.20,.40), (.20,.27))	((.40,.47), (.10,.13))	((.20,.40), (.10,.20))	((.20,.40), (.10,.20))	((.20,.40), (.20,.27))
A6	((.40,.20), (.10,.13))	((.20,.40), (.20,.27))	((.20,.33), (.10,.20))	((.20,.33), (.10,.20))	((.10,.20), (.10,.20))	((.10,.20), (.05,.07))	((.20,.33), (.20,.33))	((.20,.27), (.10,.20))	((.20,.40), (.10,.20))
A7	((.40,.20), (.05,.07))	((.20,.40), (.10,.20))	((.20,.33), (.10,.20))	((.20,.33), (.10,.20))	((.10,.20), (.05,.07))	((.60,.67), (.40,.60))	((.20,.33), (.10,.20))	((.10,.20), (.10,.20))	((.10,.20), (.10,.13))
A8	((.40,.67), (.20,.40))	((.40,.67), (.20,.40))	((.60,.67), (.40,.60))	((.40,.60), (.40,.53))	((.40,.67), (.40,.53))	((.60,.80), (.40,.53))	((.60,.73), (.40,.60))	((.60,.67), (.60,.67))	((.40,.73), (.60,.73))

with respect to the energy investment in EMR. Moreover, it is also identified that Greece and Egypt are other successful countries in this region. However, Cyprus, Libya and Syria are found as the least successful in this framework. Therefore, it is strongly recommended that especially the countries that have low performance should make investment to the distribution line of the energy and technological improvement. Furthermore, they should also give importance to the political stability. For this purpose, these countries can strengthen political relations with other countries.

The most important limitation in this study is focusing only on energy investments in the EMR. This analysis can be made for other regions where there are high energy reserves. For example, it is known that energy reserves are high in the Middle East region. However, there are many social and political problems in this region. This situation will prevent the efficient use of energy resources in the region. Therefore, a future study on this subject will contribute to the solution of these problems. Another limitation in the study is to focus only on the region where natural gas reserves are located. Thus, it is considered that it would be beneficial to carry out a similar study for renewable energy investments. On the other hand, using different methods in new studies will increase the originality. Within this context, a similar analysis can be conducted with different MCDM model. In addition, it is possible to make a numerical evaluation by considering regression and cointegration analysis.

CRediT authorship contribution statement

Yuxin Liu: Conceptualization, Methodology, Investigation, Writing- reviewing & editing. **Xue Gong:** Conceptualization, Methodology, Software, Data curation, Writing - original draft. **Serhat Yüksel:** Visualization, Investigation, Methodology, Conceptualization. **Hasan Dinçer:** Supervision, Software, Validation, Methodology, Conceptualization. **Rıdvan Aydın:** Methodology, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

See Tables A.1–A.6.

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